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A Case Study in Integrated PMESII Modeling and Simulation

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BAE Systems, Advanced Information Technologies
76th MORSS, WG-1 & WG-8, June 10-12, 2008

This material is based upon work sponsored by USAF under Contract No. FA8750-06-C-0086 and SPO700-98-D-4000 Delivery Order 52, Subcontract #303991

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 JUN 2008	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
A Case Study in Integrated PMESII Modeling and Simulation	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **BAE Systems, Advanced Information Technologies**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM202527. Military Operations Research Society Symposium (76th) Held in New London, Connecticut on June 10-12, 2008, The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**32**	

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Agenda

- Background – Evaluating CMIST
  - What is CMIST?
  - Evaluation goals
  - Pacifica overview
- PMESII Modeling
  - Modeling methodology
  - PsyOps/MCO model
- Experimental Results
  - Running different COAs
  - COA Comparison & Drilldown
- Lessons Learned
  - Modeling process
  - Tool insights
- Future Work
- Conclusions

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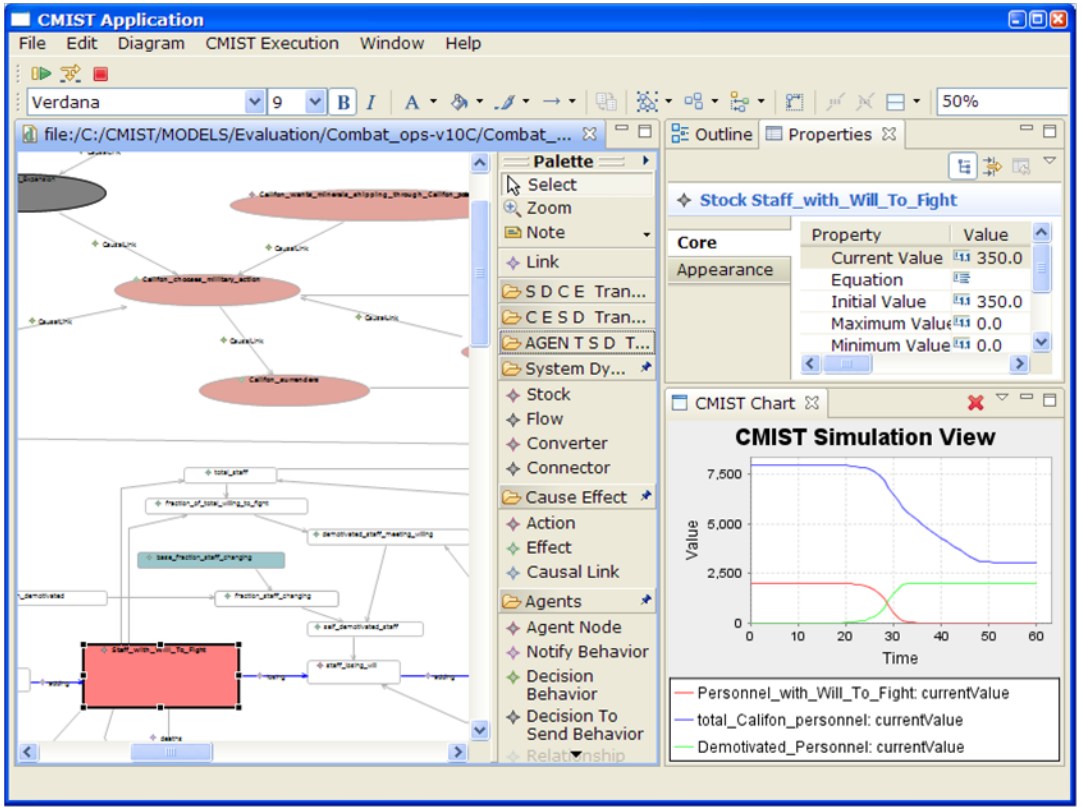
CMIST Overview

- Multi-Methodology M&S IDE
  - Modeling tools for authoring, debugging, simulation, visualization, exporting
  - Developer tools for authoring new ontologies, integrating native simulation tools
- Built on proven open standards and C/GOTS
  - Plug-ins to the widely-used Eclipse Java IDE
  - XML, XSD, UML, XDA, OAT



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Families of Simulation Methodologies

- Methodologies currently incorporated in tool
  - Cause-effect (AFRL CAT)
  - System Dynamics (U. Berkeley's Ptolemy II)
  - Agent-based modeling (TILab's JADE)
- Methodologies being incorporated this year
  - Bayesian Knowledge Bases (E. Santos, Dartmouth College)
  - Colored Petri Nets
  - Network links to data sources (not really a methodology)
- Extensible libraries
  - Transforms for cross-model data exchange
  - Interaction patterns for synchronizing models with disparate time management

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CMIST Evaluation Goals

- Mission Statement
  - Evaluate and assess the **utility, robustness and relevance of CMIST** to provide command-level decision makers the **capability to anticipate and shape future battlespaces**
- Resources
  - CMIST 1.0 from previous effort (see MORSS 75th EBO SS)
  - Unclassified Pacifica dataset (use and augment as needed)
- Specified Tasks
  - Identify scenario-specific requirements, data and models
  - Define models and input data needed to apply CMIST
  - Exercise CMIST PMESII modeling capabilities in a realistic context
  - Evaluate the performance, efficacy and utility of CMIST
    - Strengths and weaknesses
    - Gauge appropriateness for COA generation and assessment
- Endstate
  - CMIST demonstration and tutorial using the Pacifica-based scenario
  - Final report on evaluation criteria and metrics, planning process, tool operation

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PMESII Modeling Methodology

1. Develop an issue statement
2. Identify key variables & other data
3. Define reference behavior patterns
4. Develop a structural dynamic hypothesis
5. Build a simulation model
6. Iterate, improve, and implement

Modeling Focus: PsyOps impact on Major Combat Operations

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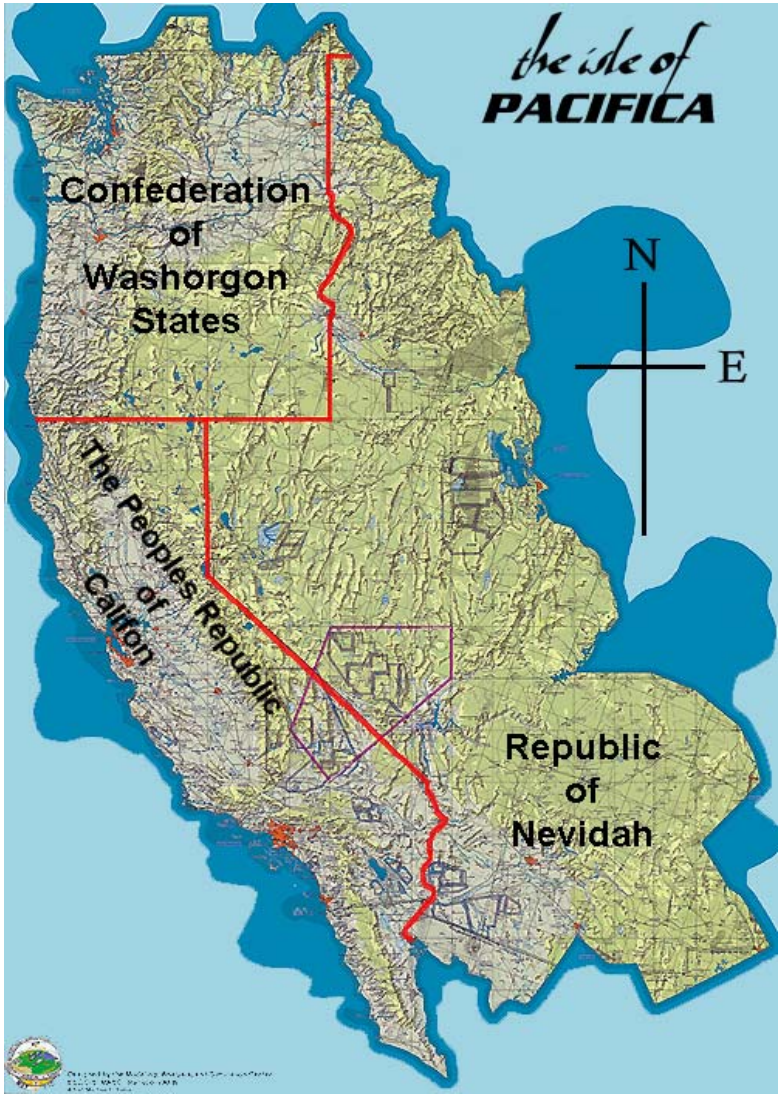
Pacifica Overview

- Red strategy (Califon)
  - **Goal:** Prevent Nevidah development of port of Salt Lake City
  - **Actions:** Invade Nevidah to take mineral fields with conventional military forces
- Blue strategy
  - Ph I: Deterrance through defensive deployment, Info Ops, COIN Ops
  - Ph II & Ph III – Major Combat Ops
    - Ph II: Seize the Initiative through air superiority, begin offensive counter-land
    - Ph III: Decisive Ops: Attrit Califon army, WMD, and offensive capability
  - Ph IV: Transition: Monitor, support, redeploy



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1. Issue Statement

- Models will compare **PsyOps** non-kinetic strategies with a conventional scenario of Major Combat Operations (**MCO**)
- Focus on aggregate values such as **Land Area** and **number of personnel**, but create individuals such as **Red Commander** for decision-making
- Model the Califon military organization featuring three levels of hierarchy:
  - Commander
  - Staff
  - Personnel.
- The lower two levels can be influenced by PsyOps campaign, which reduces the will to fight of Califon personnel and staff

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2. Key Variables

- A few key variables are listed below. During this stage of the modeling process, we are trying to outline some important features, but we will revisit and add variables as we go

- Califon combat power (personnel + equipment)
  = Califon force factor
- Blue combat power (similar)
- Land gained by Califon (in contested PMF region)
- Califon personnel with will to fight
- Blue personnel and equipment losses
- Califon decisions (invade or not, retreat, etc.)
- Califon Commander

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Scenario 1 – MCO with Close Air Support

- Califon invades Nevidah on day 2
  - Califon decisions in Cause-Effect methodology feeds into Agent model of Califon Commander, and decision output of military action and/or surrender feeds into the larger System Dynamics model
  - Nevidah land (mineral fields) under Califon control is a major indicator
- Blue starts MCO on day 30
  - Blue commanders are Agents with deterministic decisions which are played out in the System Dynamics model

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Scenario 2 – MCO with PsyOps only targeting Personnel

- Same basic structure as Scenario 1

- PsyOps campaign initiated by Joint Commander on day 18
  - Califon **Personnel with Will To Fight** targeted by PsyOps campaign (Holdouts are not targeted by campaign)

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Scenario 3 – MCO & PsyOps targeting Personnel & Staff

- Same basic structure as Scenario 2

- PsyOps campaign initiated by Joint Commander on day 18
  - Califon **Personnel with Will To Fight** and **Staff with Will To Fight** are both targeted by PsyOps campaign
  - These two organizational levels interact with each other in a **positive feedback fashion**, resulting in much faster rates of demotivation

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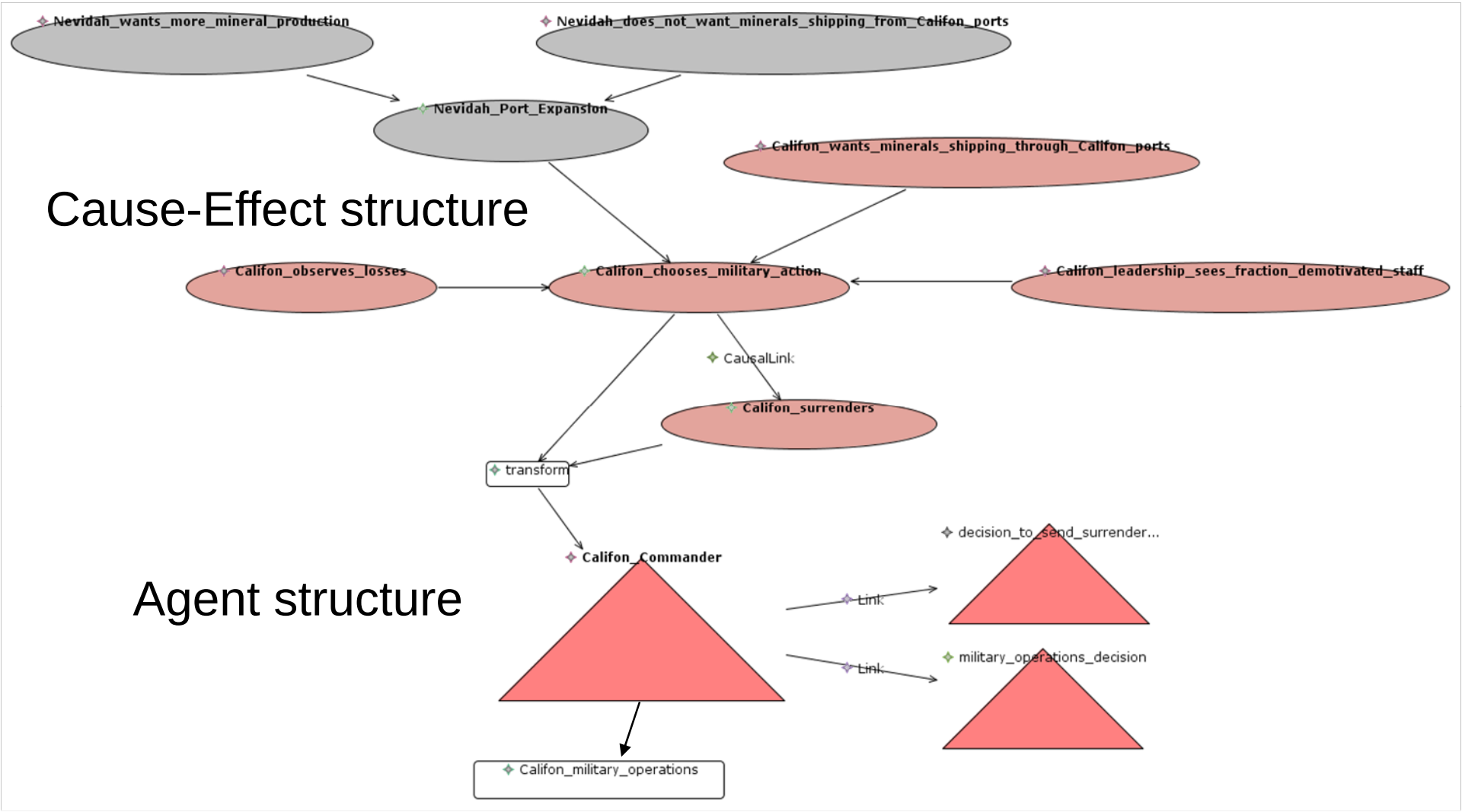
Califon Decisions – Cause Effect & Agent Model



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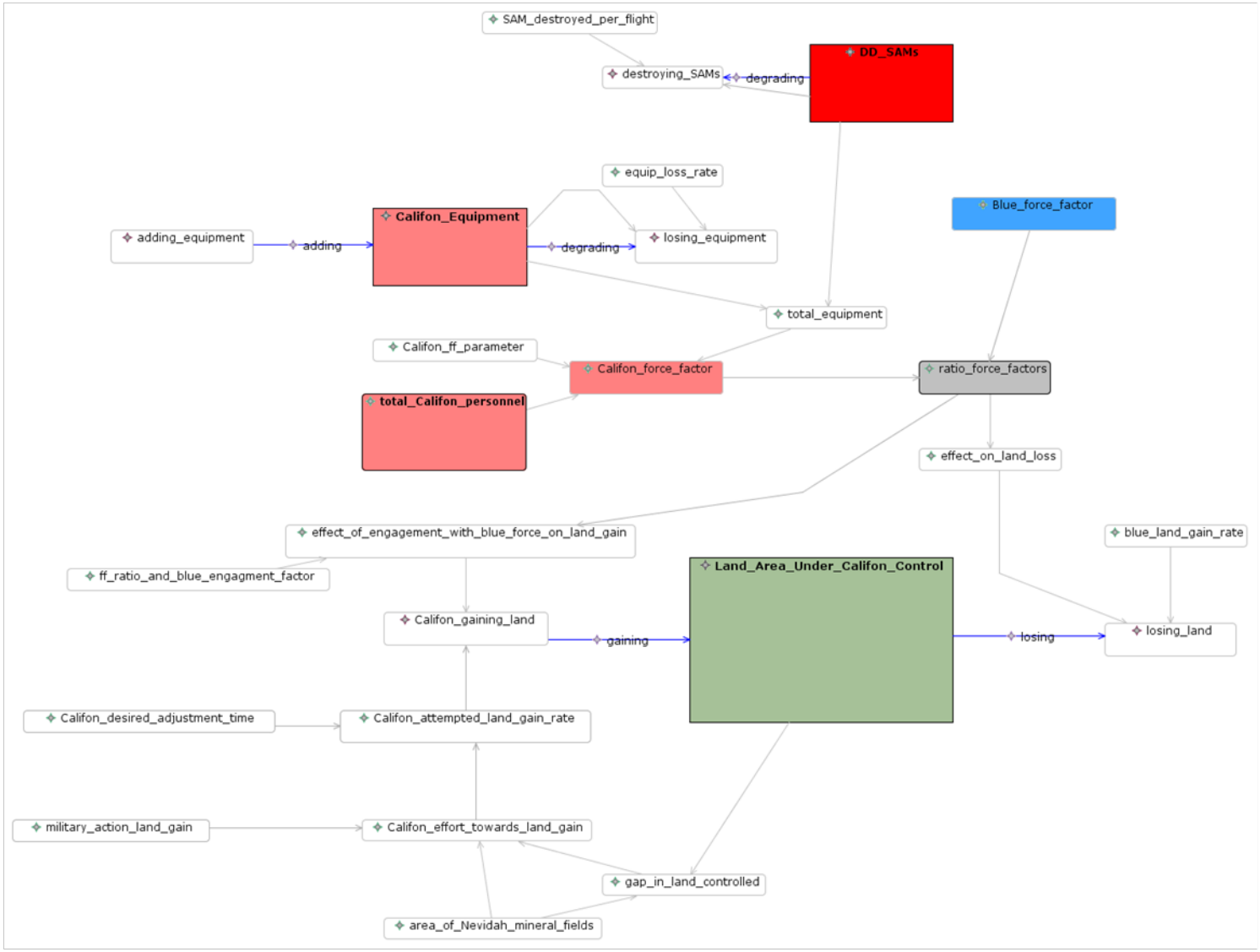
Califon Force Factor & Land Gain – System Dynamics (SD)



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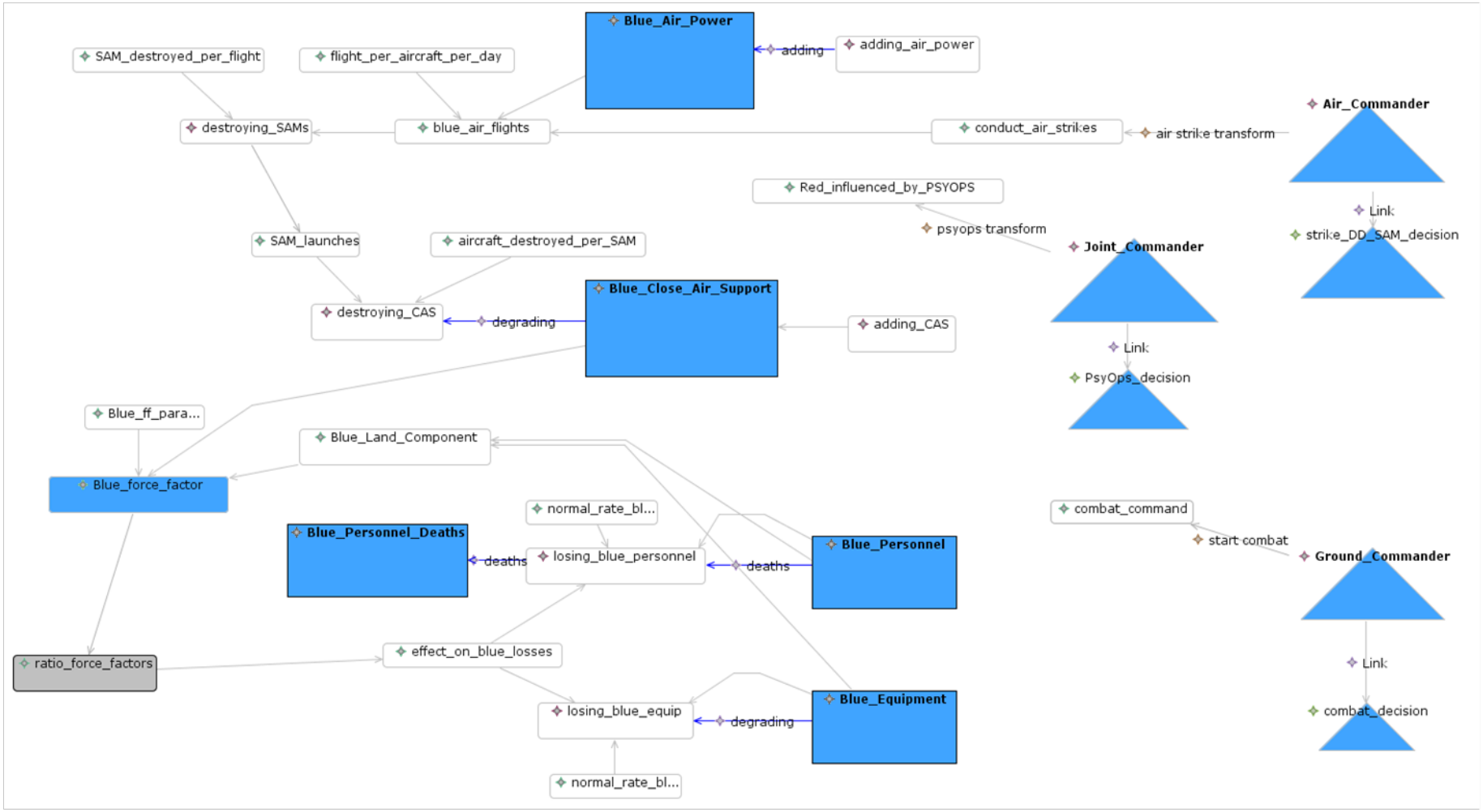
Major Combat Operations, Blue Forces – SD & Agent



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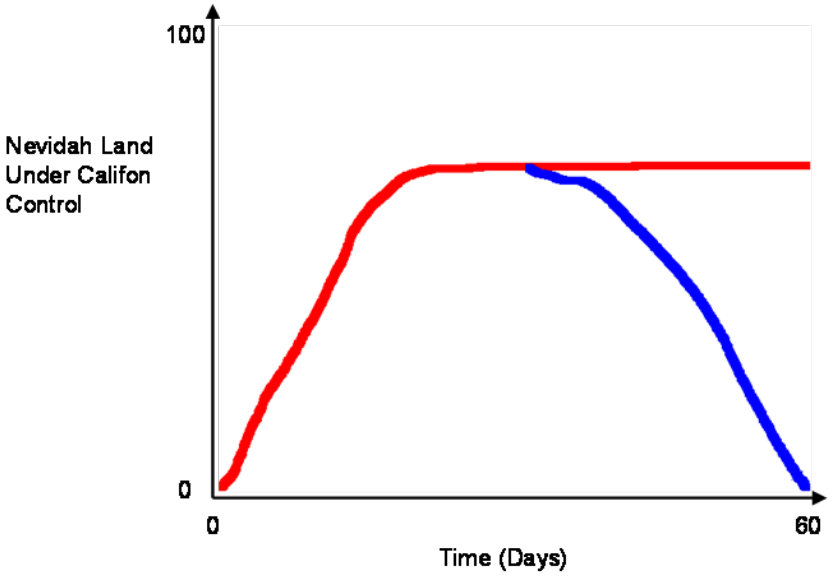
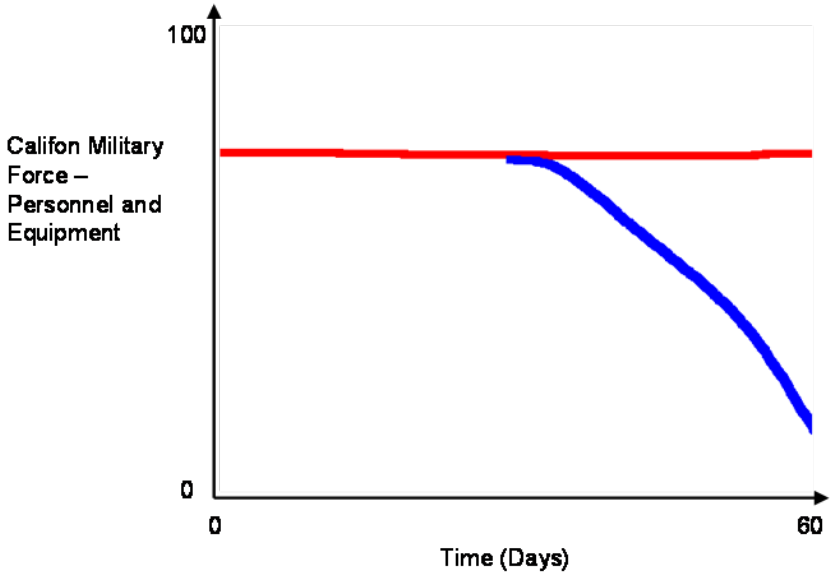
PsyOps/MCO Reference Behavior Patterns – 1

- Reference behavior patterns display historical or expected future values for a variable as a time-series





- Time horizon is zero to 60 days into the future
- Red line shows expected behavior pattern for Califon if no Blue intervention
- Blue line shows expected behavior when Blue launches Major Combat Operations – increasingly steep losses for Califon

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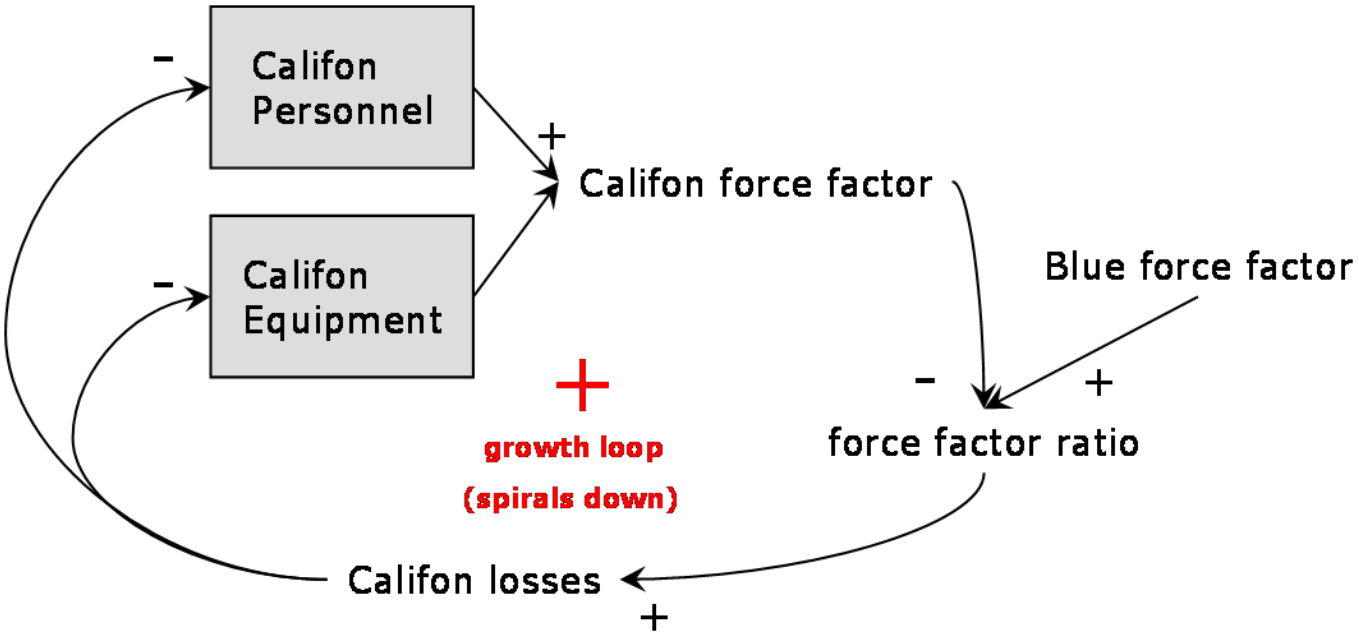
Structural Hypothesis – 1

- Force-on-Force interactions apply attrition rates proportional to the force factor ratio (Califon) or its reciprocal (Blue)
- Potential for spiral downwards when your force factor gets smaller

$$\text{force factor ratio} = \frac{\text{Blue force factor}}{\text{Califon force factor}}$$



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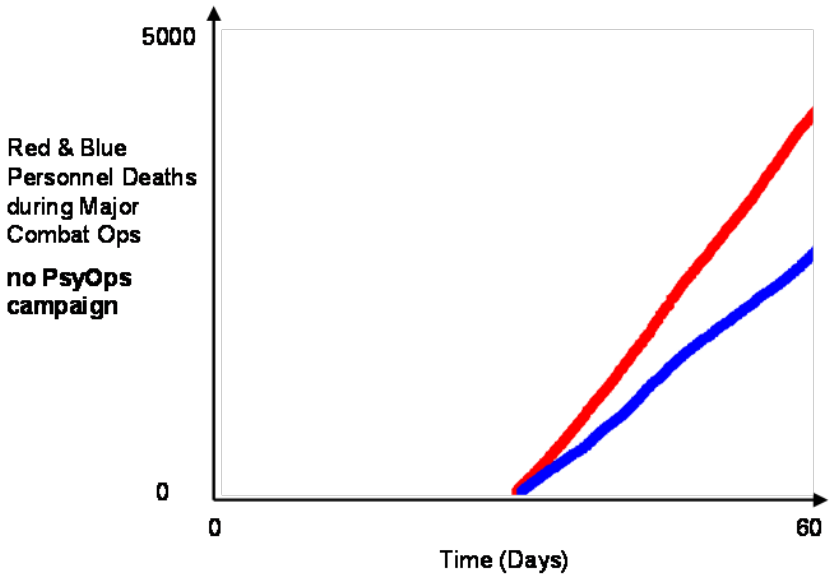
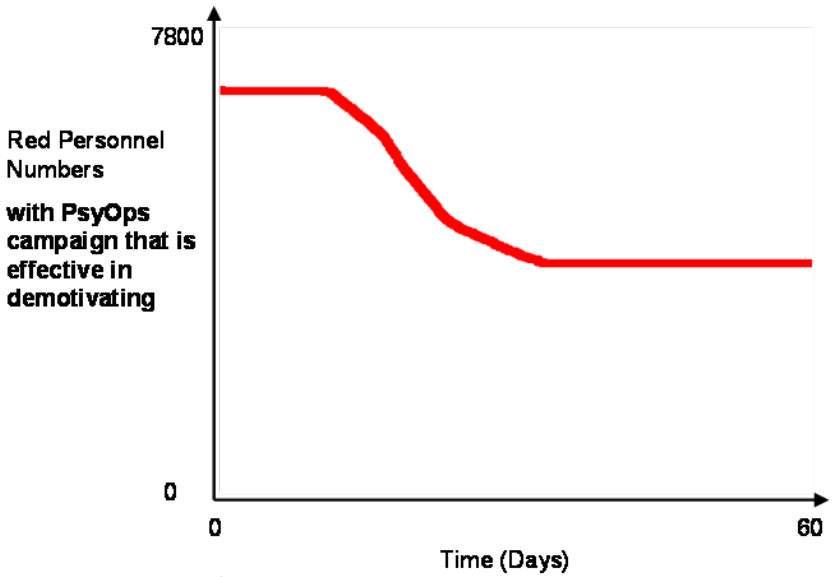
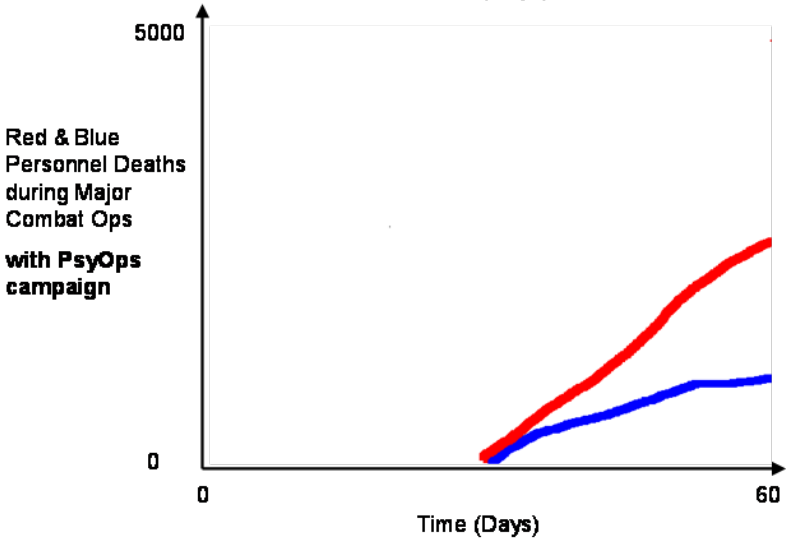
PsyOps/MCO Reference Behavior Patterns – 2







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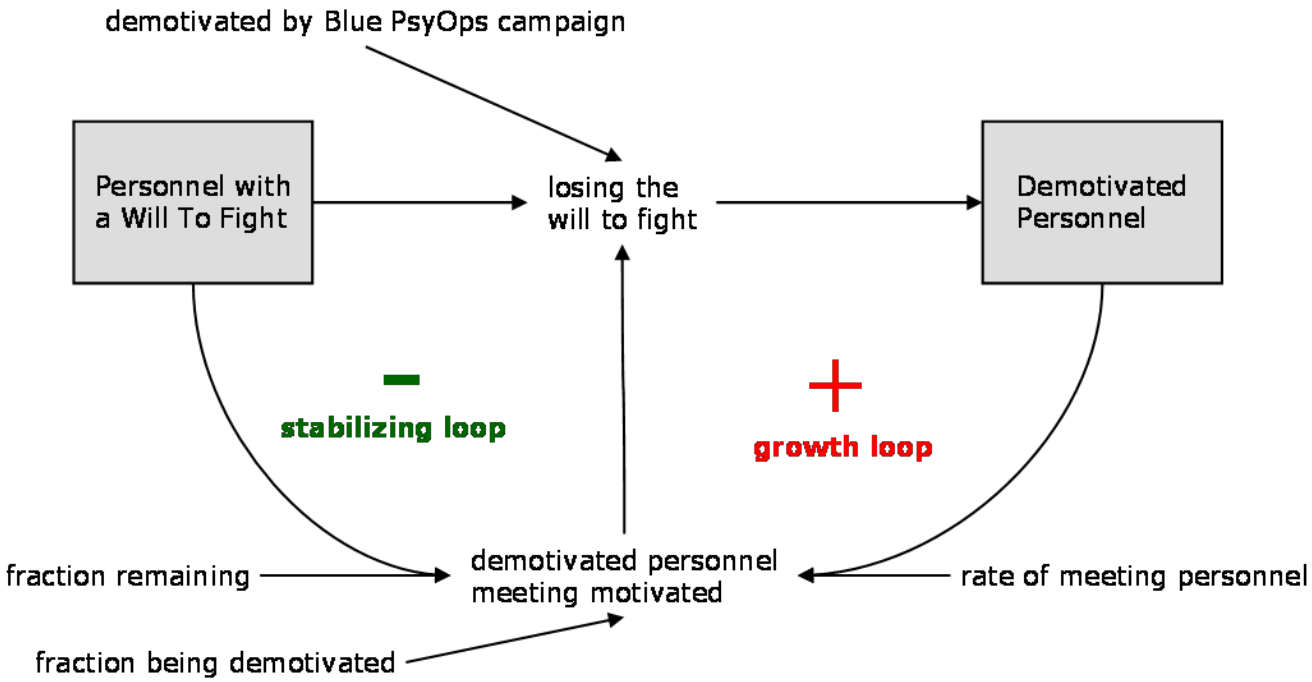
Structural Hypothesis – 2

- PsyOps campaign starts demotivation in Califon personnel & staff
- Which then self-reinforces through social processes such as word-of-mouth and observations of others demotivating



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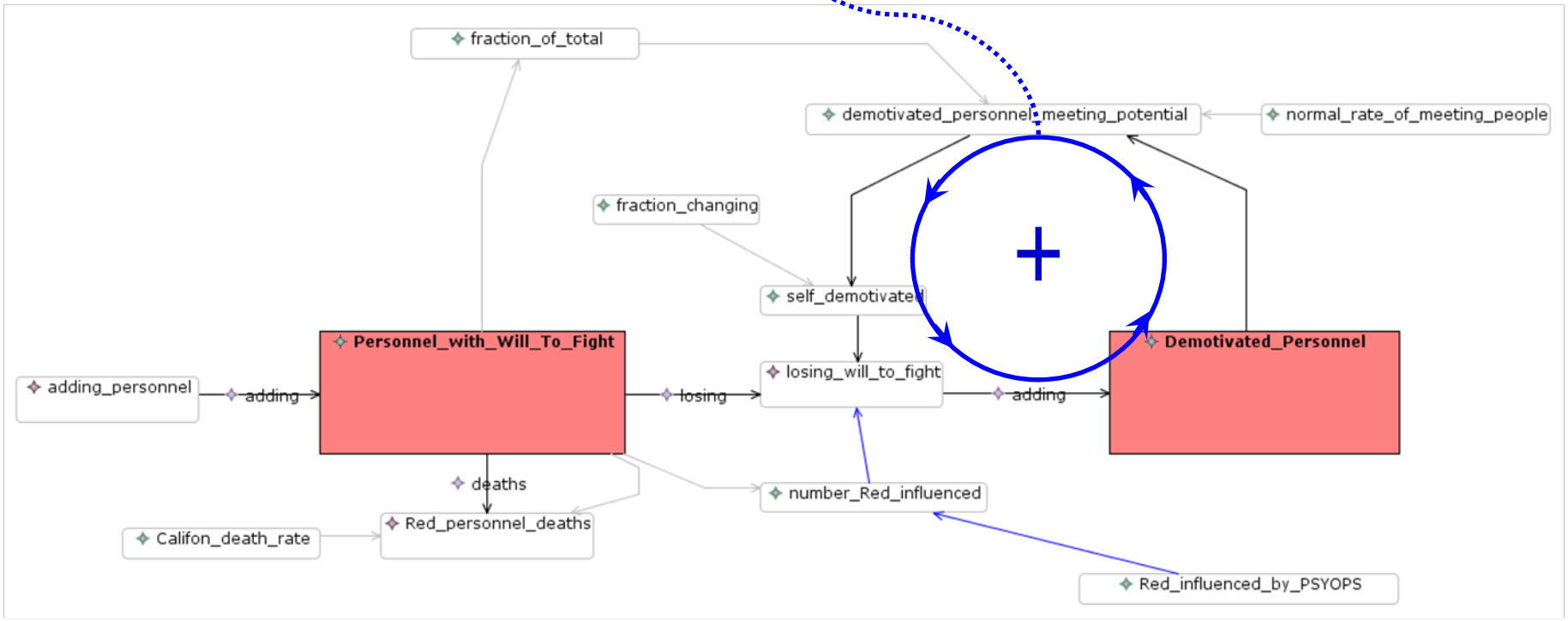
Will To Fight Demotivation Structure – SD

Positive feedback growth loop of Demotivated Personnel



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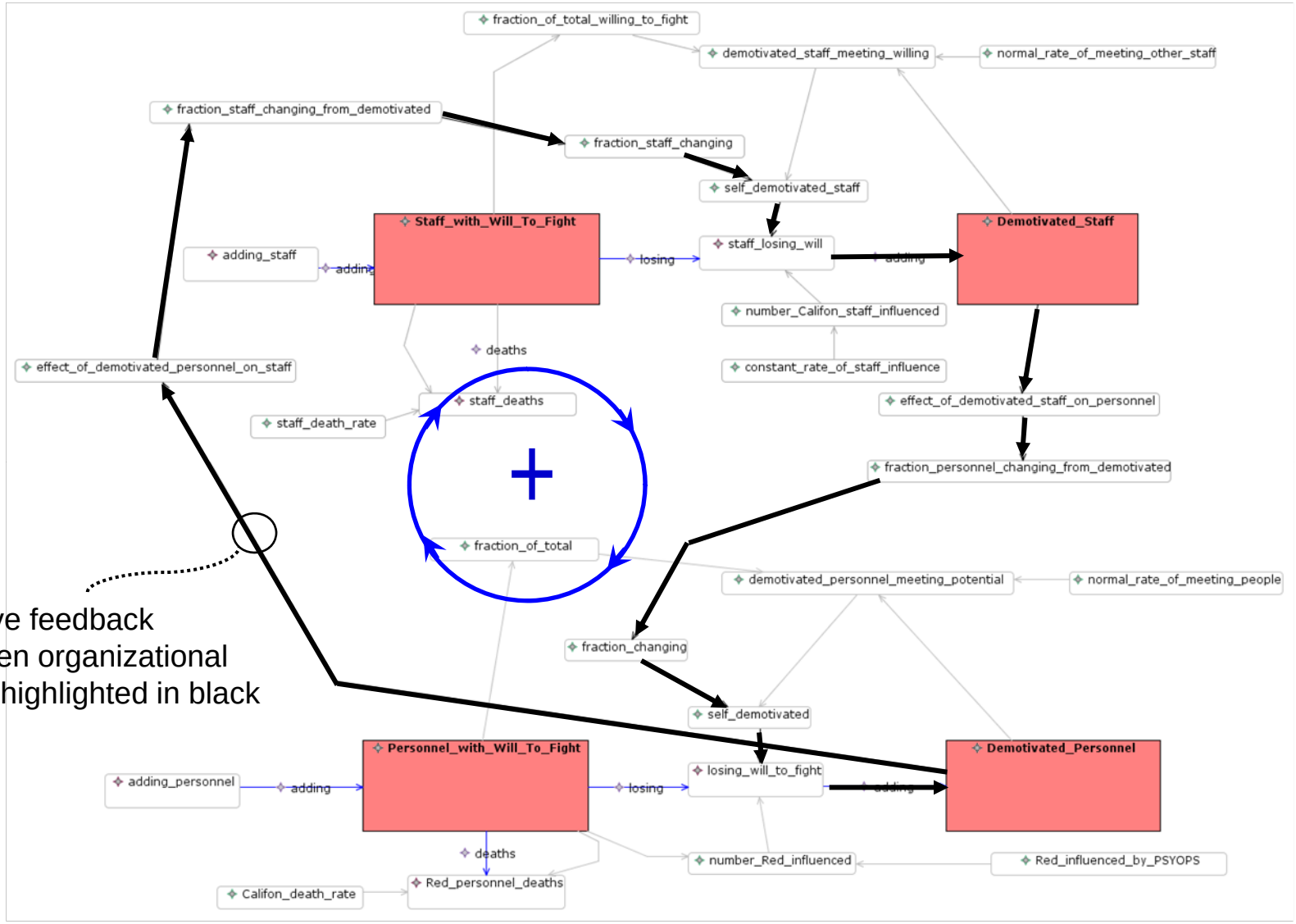
Demotivation Across Califon Organization – SD



Positive feedback between organizational levels highlighted in black

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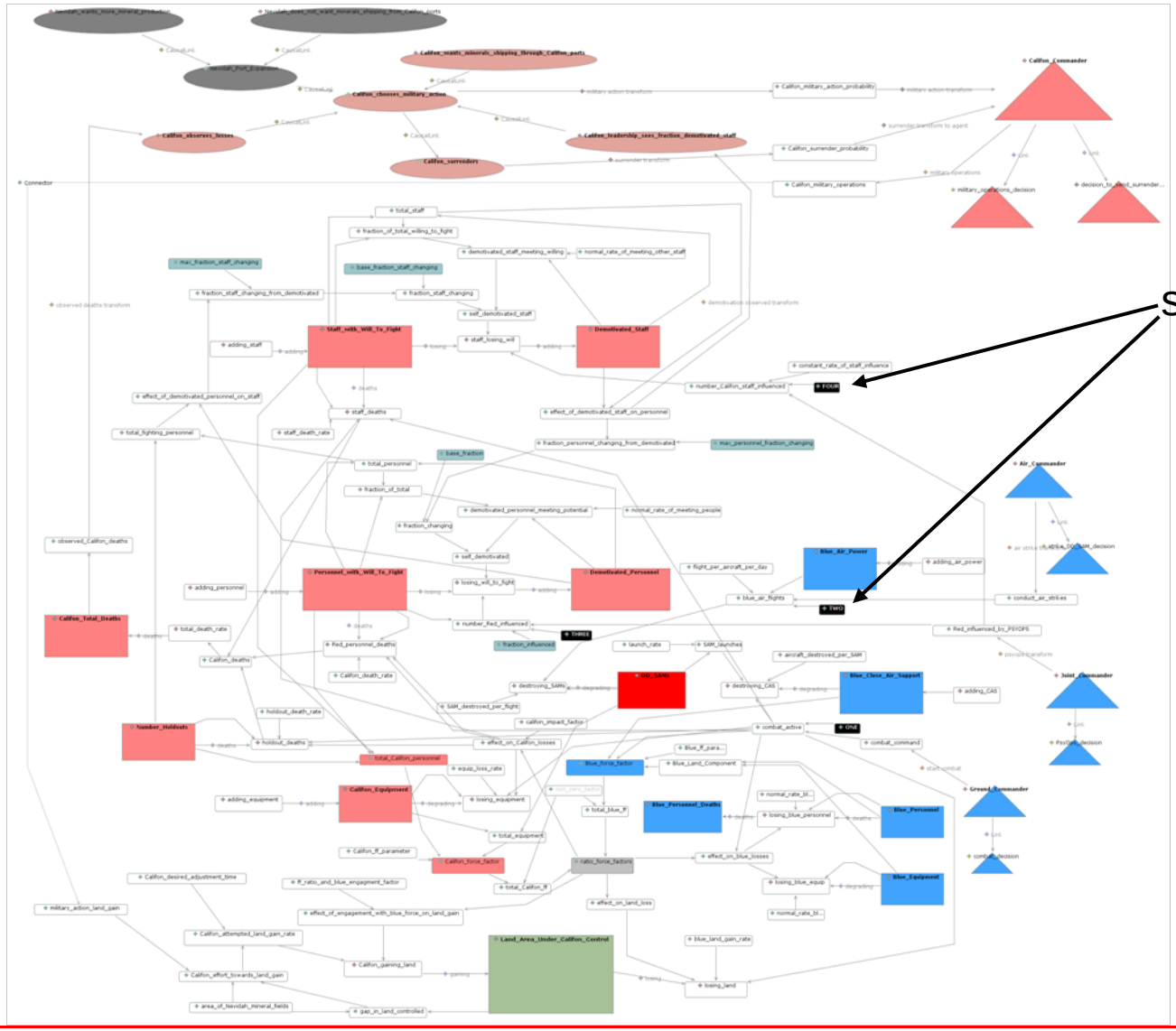
Califon Will To Fight / Blue MCO Model



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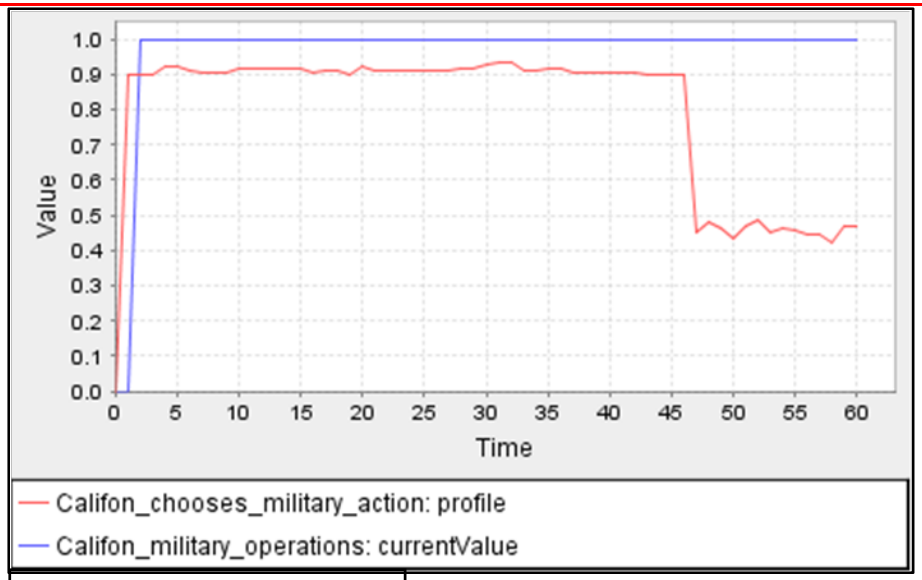
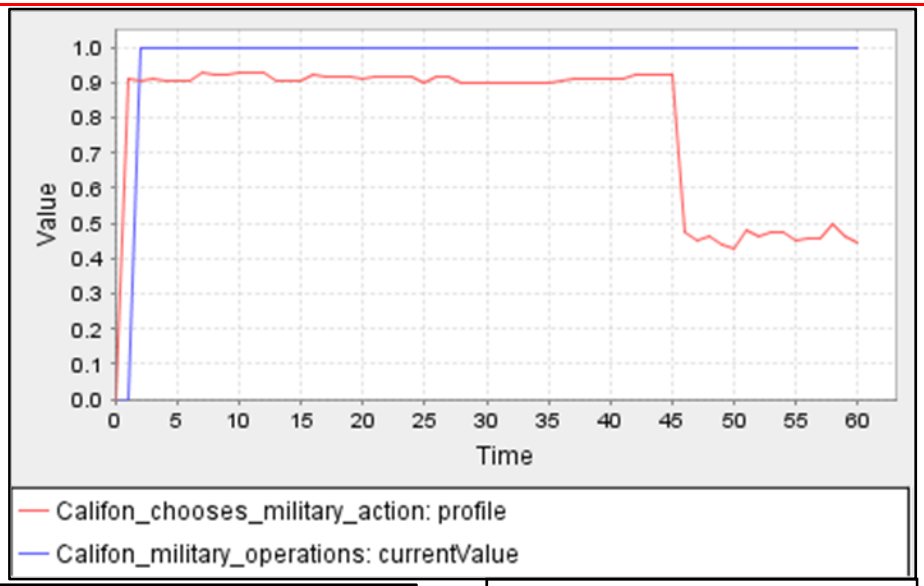
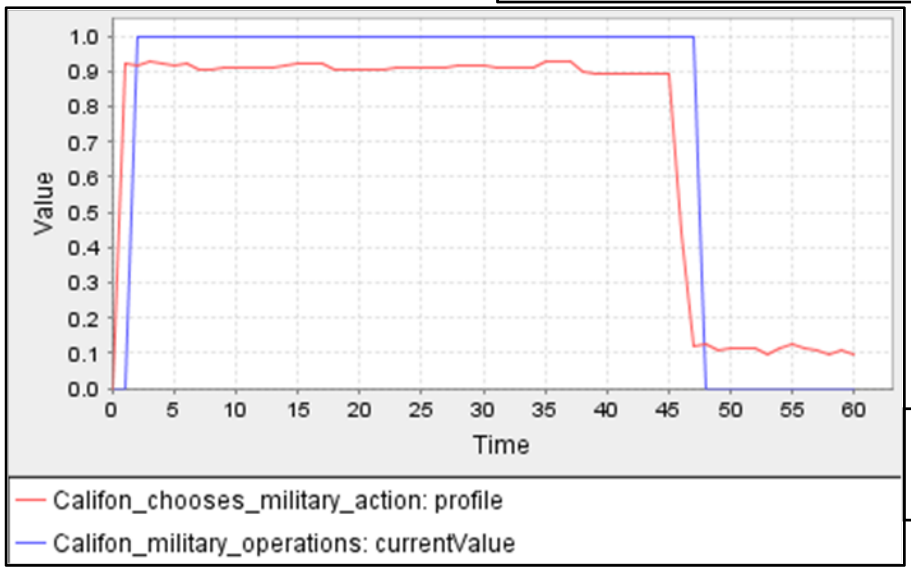
When Califon attacks & Probability of continuing to fight



COA 1 – MCO with Close Air Support



COA 2 – MCO + PsyOps on Personnel



COA 3 - MCO + PsyOps on Personnel & Staff

Data presented here are based on notional or open source information

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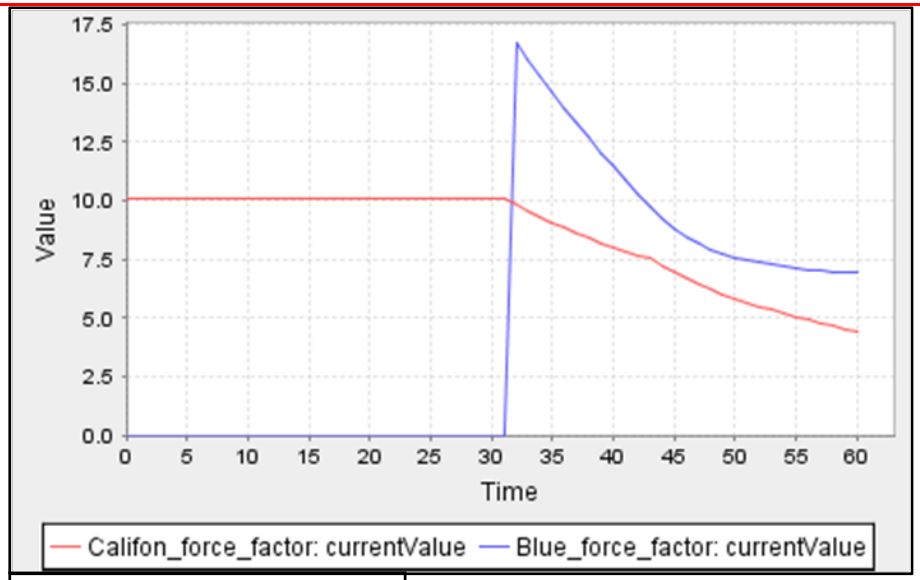
Red and Blue force factors



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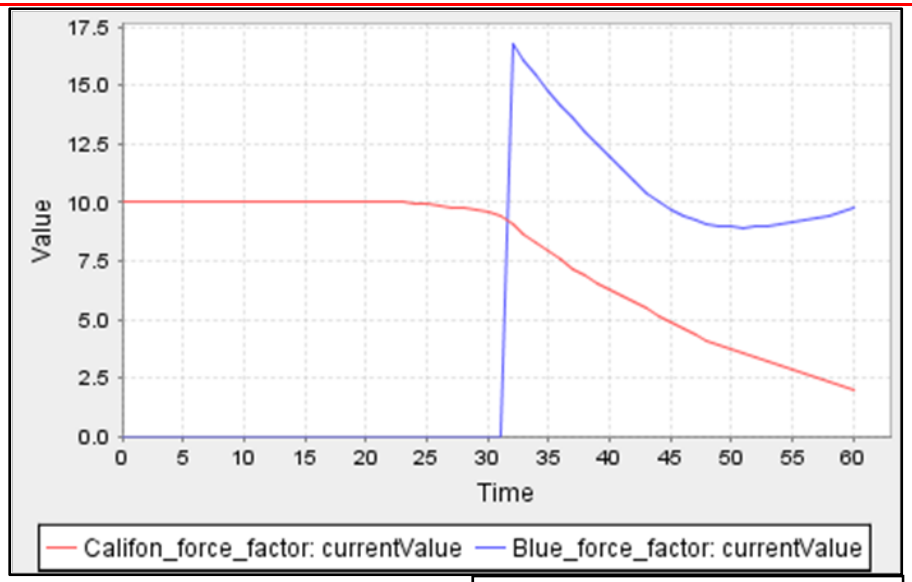
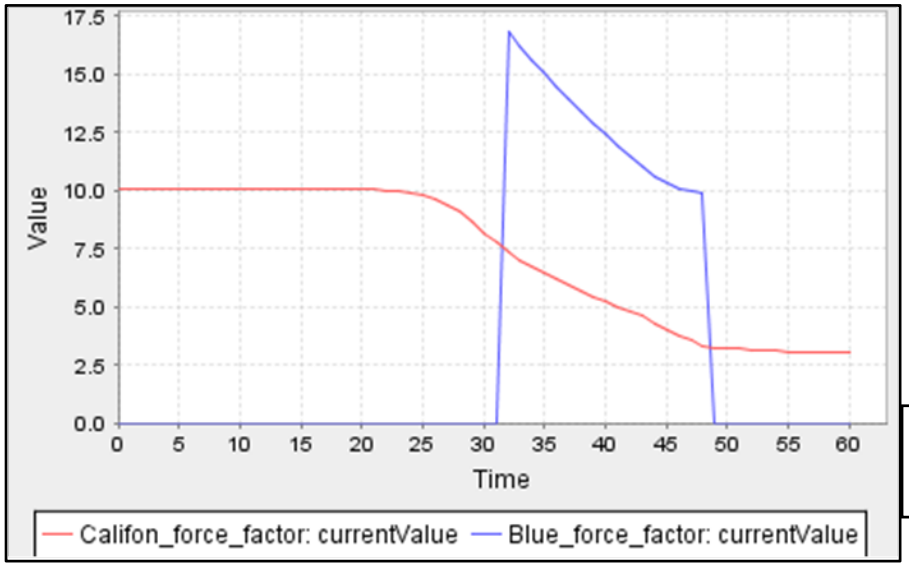


COA 2 – MCO + PsyOps on Personnel



COA 3 - MCO + PsyOps on Personnel & Staff

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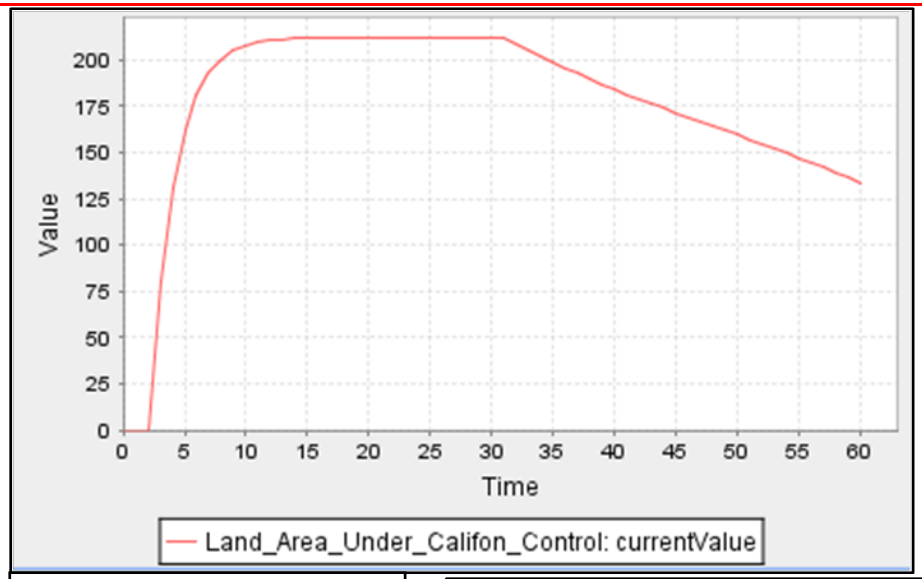
Land under Califon control



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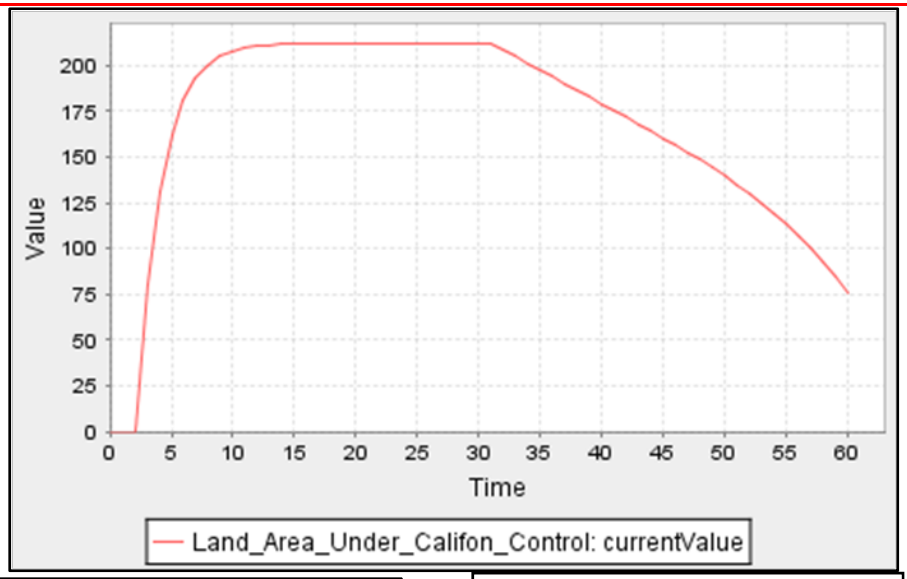
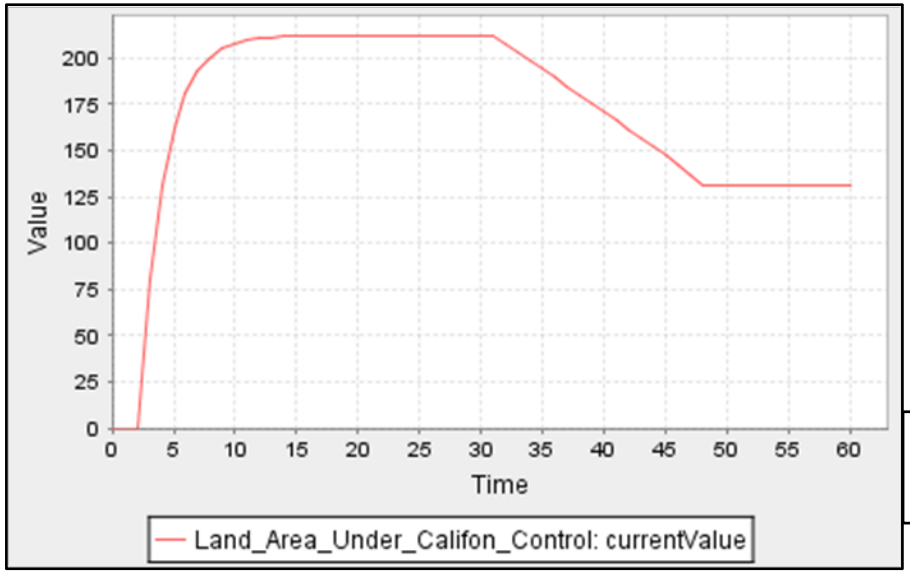


COA 2 – MCO + PsyOps on Personnel



COA 3 - MCO + PsyOps on Personnel & Staff

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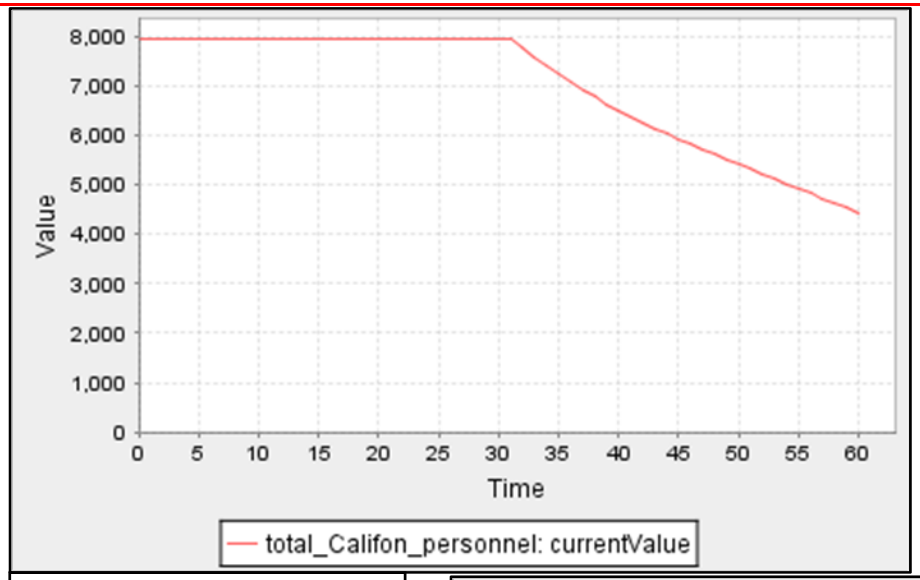
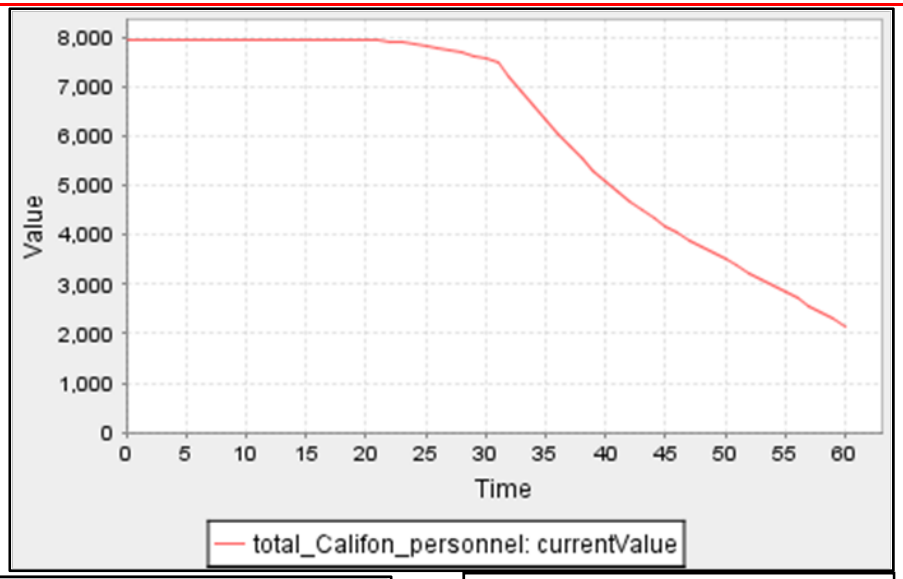
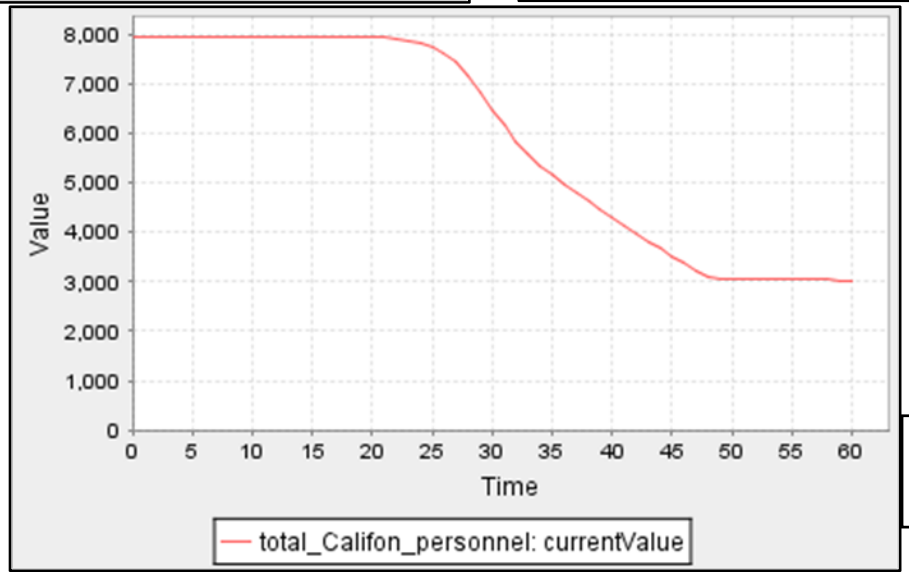
Total Califon personnel (including holdouts)



COA 1 – MCO with Close Air Support



COA 2 – MCO + PsyOps on Personnel



COA 3 - MCO + PsyOps on Personnel & Staff

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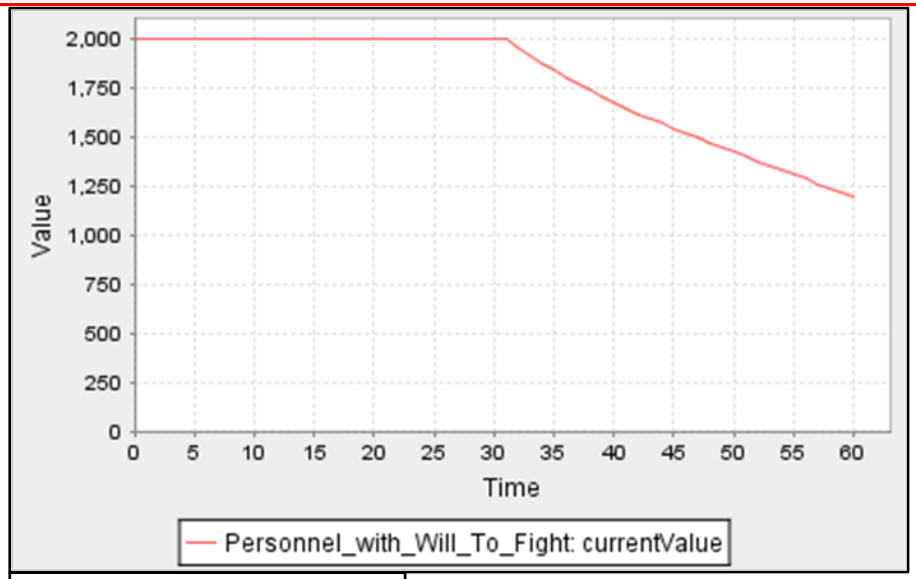
Personnel with will to fight (not including holdouts)



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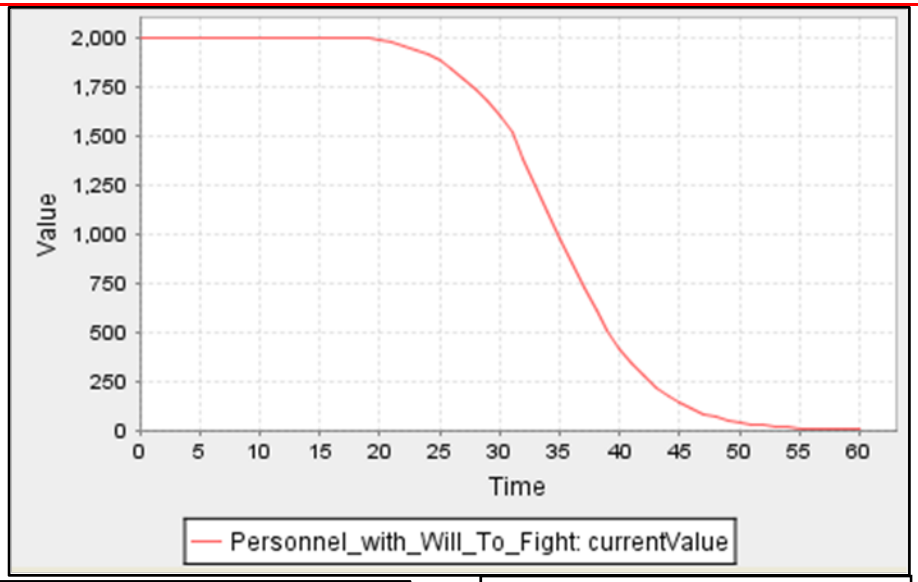
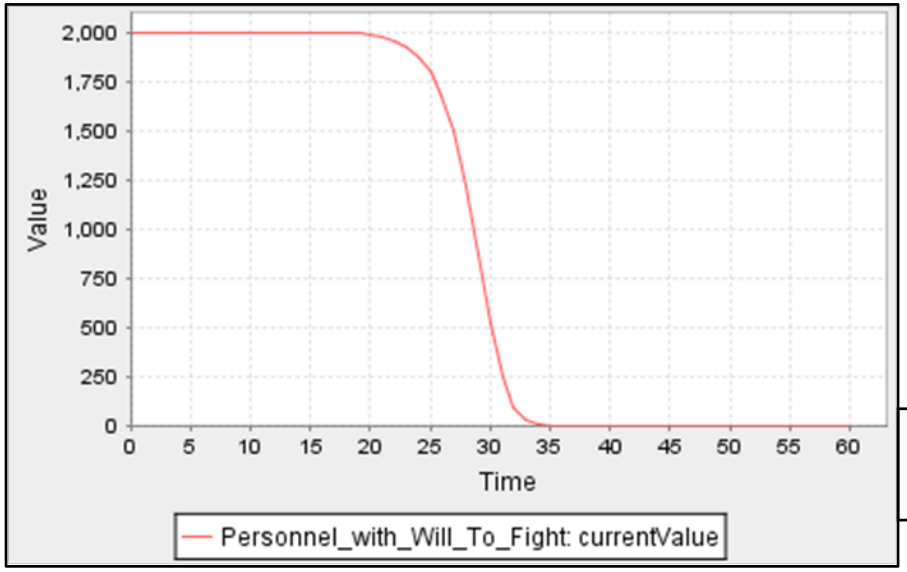


COA 2 – MCO + PsyOps on Personnel



COA 3 - MCO + PsyOps on Personnel & Staff

Data presented here are based on notional or open source information

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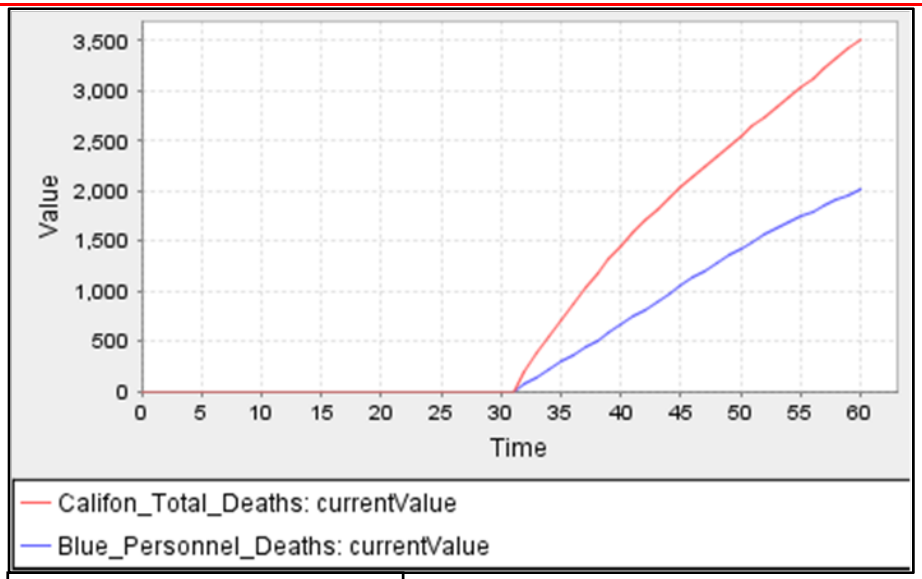
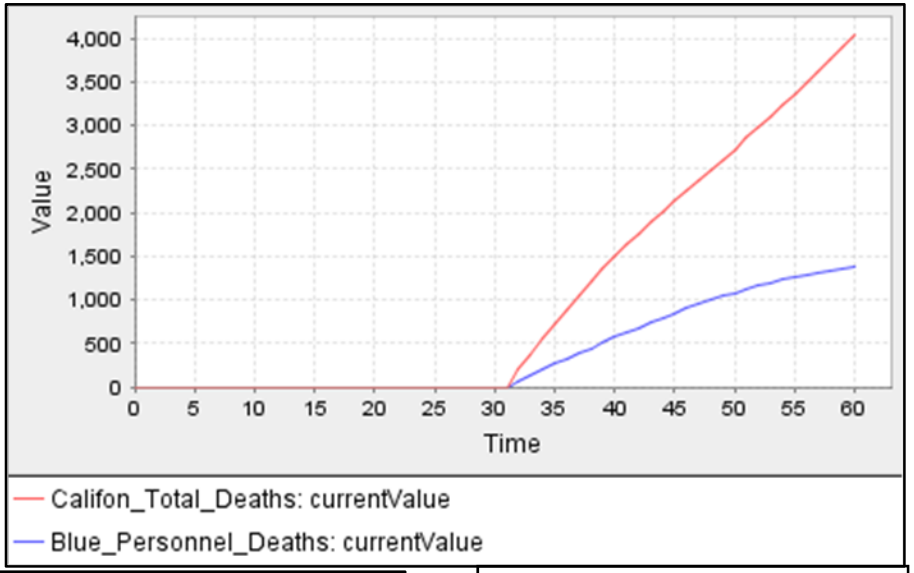
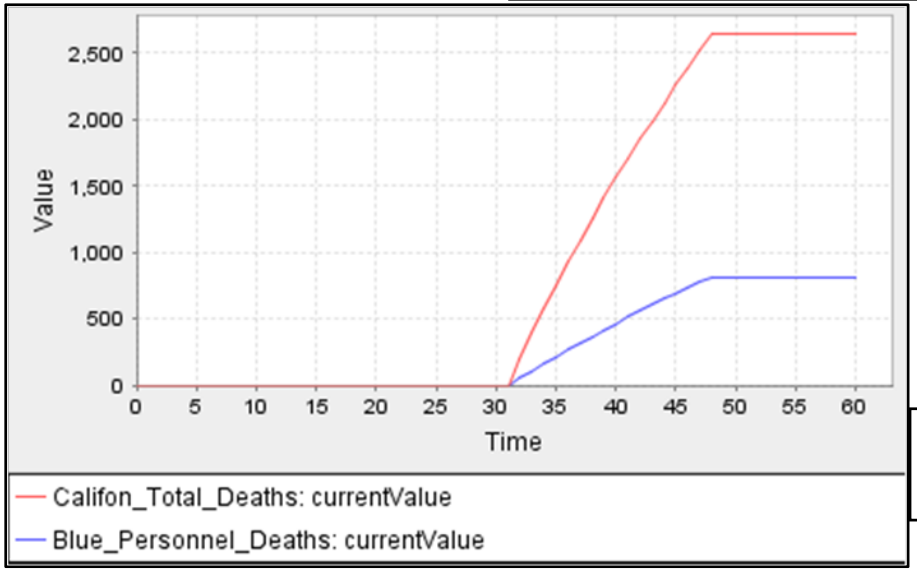
Red vs. Blue casualties by attrition



COA 1 – MCO with Close Air Support



COA 2 – MCO + PsyOps on Personnel



COA 3 - MCO + PsyOps on Personnel & Staff

Modeling Lessons Learned

- Promising initial results mixing modeling methodologies
  - Successfully demonstrates CE-SD-Agent interactions
  - Combines native tools with discrete vs. aggregate time management
- Useful results on Califon/Blue MCO/PsyOps model
  - Demonstrates ability to model soft factors, such as psychological influence campaign on adversary and the resulting social dynamics
  - Can mix probabilistic Cause-Effect trees with Agent logic structures to represent decision-making under uncertainty
  - Can test assumptions, both structural and numerical, in experiments:
    - What happens if we increase the effort in PsyOps? (numerical)
    - What if we start PsyOps earlier, or later? (numerical)
    - What outcomes result if we target adversary officers/staff in PsyOps campaign as well as their personnel? (structural)
- Other modeling work
  - Earlier work with CMIST generated a PMESII notional insurgency model, demonstrating effects of unemployment, insurgent recruitment, and impacts of aid programs
  - Usable for modeling DIME, PMESII, counter-insurgency, information ops, etc.

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Tool Lessons Learned

- CMIST provides a rich platform for PMESII model integration
  - M&S developers IDE to rapidly integrate new native simulation tools (on the order of a few weeks)
  - Commander's IDE for rapid model authoring, execution, and refinement (develop simulating models in as little time as a few hours)
- CMIST lacks some features of more-developed simulation tools
  - Syntax checking of model equations, arbitrary lookup functions, saving simulation data for reuse & comparison, multi-level display of node-link models, senstitivity testing, optimization, etc.
  - We are addressing some of these features in CyberCAFE
- Leveraging open-source community's work
  - But need to be careful to mark your code so you can update to new releases
- Enthusiastic response from Air Force SME; potential future as modeling tool for rapid construction of low-overhead models

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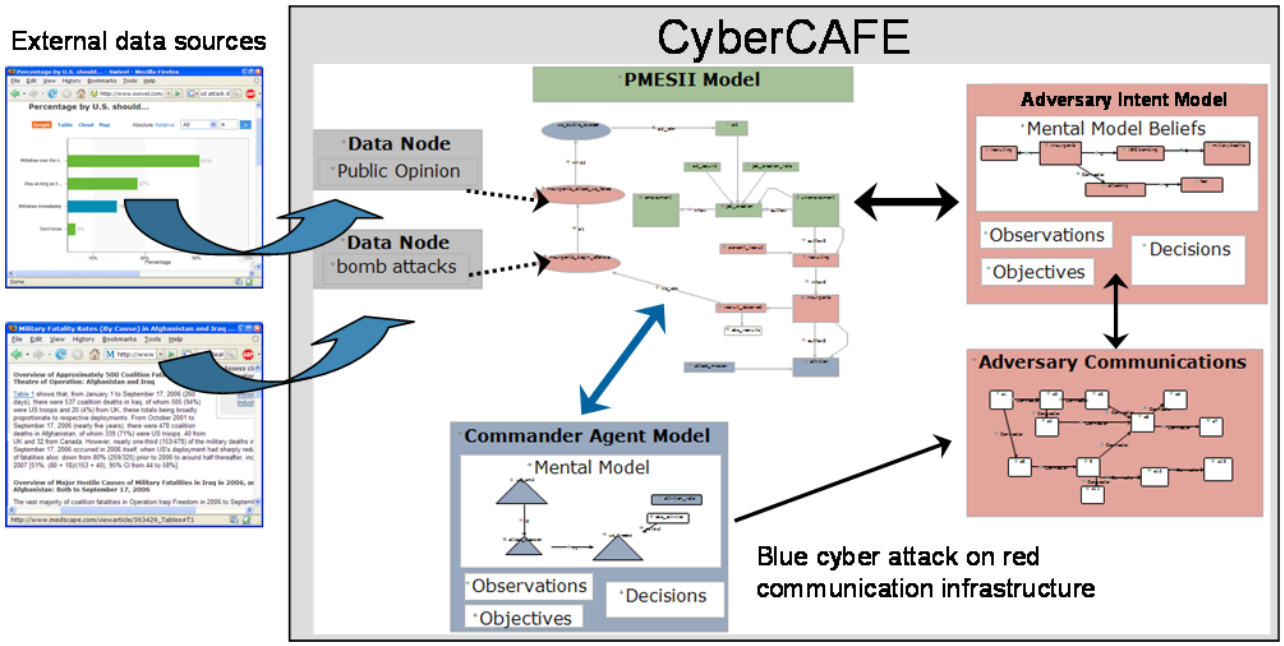
Future Work



CyberCAFE – Cyber-PMESII Commander's Assessment of Forecast Effects

- Unified cyber-PMESII modeling environment built on CMIST IDE
- Intent Modeling for friendly, neutral, adversary agents
- Temporal Bayesian Knowledge Bases capture beliefs, rationales, actions, effects (what, why, how)
- Embedded agent simulations distinct from main world enable complex deception strategies
- Colored Petri Nets enable information flow modeling for cyber-COA analysis
- Connection to Live Data Sources, Web-based or database sources to inform model inputs
- Comparative observational data helps validate model outputs

Acknowledgments

- Sponsors
  - AFRL RRS Commander's Predictive Environment
- Co-authors
  - Nicholas J. Pioch (PI)
  - James Melhuish (Modeling Lead)
  - Mike Cook (SW Lead)
- CMIST Team
  - Mike Cook, Andrew Seidel (Developers)
  - James Melhuish, Nicholas Pioch (Modelers)

This material is based upon work supported by the United States Air Force Research Laboratory under Contract No. FA8750-06-C-0086 and SPO700-98-D-4000 Delivery Order 52, Subcontract #303991. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the United States Air Force.